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Electrostatically Focused Multibeam Klystron

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We report on our work to build and test an electrostatically focused 7-beam klystron oscillator with output power of 2 KW at frequency 5.8 GHz. A photo of it is shown in Figure 1. This tube was developed to drive the plasma production of a gridded ion thruster. The microwave thruster was being developed because of the long life offered by microwave electron cyclotron resonance plasma sources.*

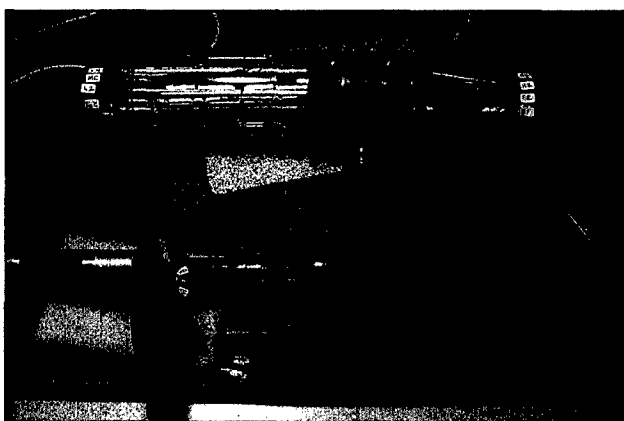


Figure 1

Electrostatically focused multiple beam klystrons (ESFMBKs) have several advantages over other klystrons. Among these are higher basic efficiency, wider bandwidth, and lower beam voltage. Advantages over magnetically focused multibeam klystrons include much lower mass and size, and lower cost and complexity. Construction technology is sufficiently low-cost and amenable to volume production that we envision

ESFMBKs in the low and medium power commercial amplifier markets. Cost per watt below \$10 seems feasible. We will discuss these opportunities.

Tube data and features are summarized in Table 1. The emission sources are 7 flat osmium tungsten mixed matrix dispenser cathodes, loaded at 3.5 A/cm^2 and only .080 inches in diameter. Their small size and low capacitance allows beam current modulation. Beam cut-off occurs at 800 volts with respect to the focus electrode. A photo of the focus electrode plate is shown in Figure 2, and a diagram of the electron gun is shown in Figure 3. Figure 4 shows an RF cavity in cross-section. There are 3 cavities and each is split at the cavity gap, with a step up in voltage which improves focusing. An insulator lies between the cavity halves and allows a step up to 10,000 volts without breakdown. However, a step up of 4,000 volts is proving adequate.

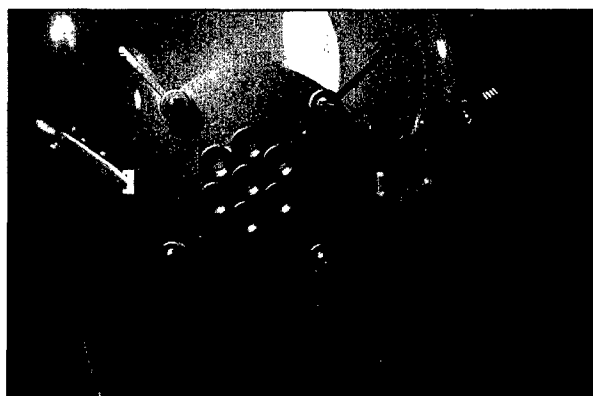


Figure 2. Focus Electrode Plate

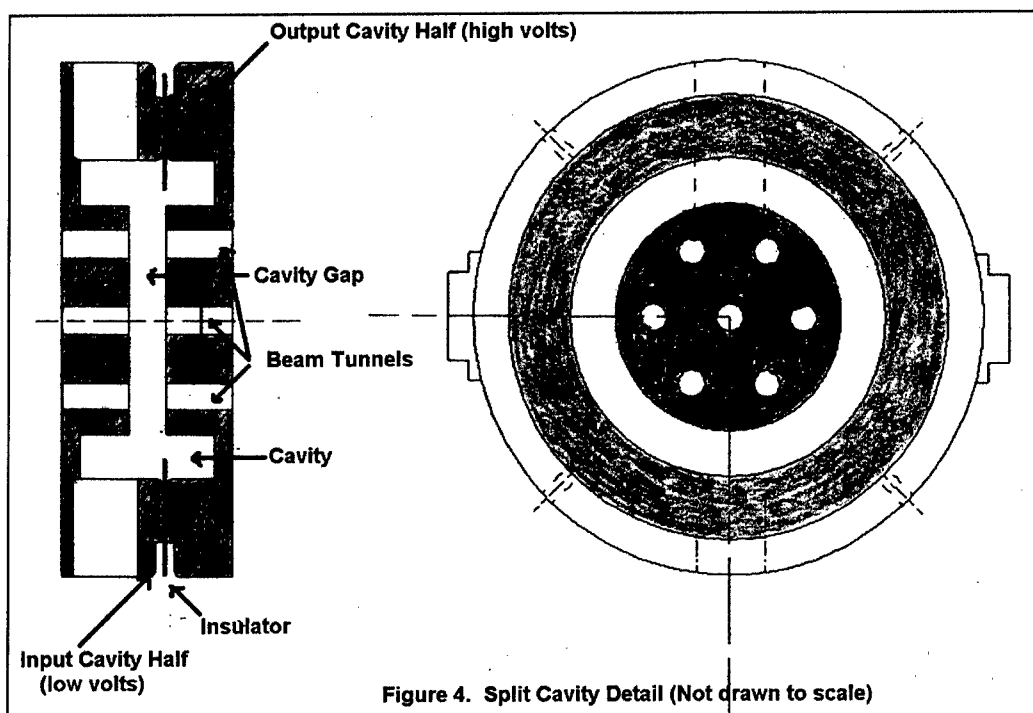
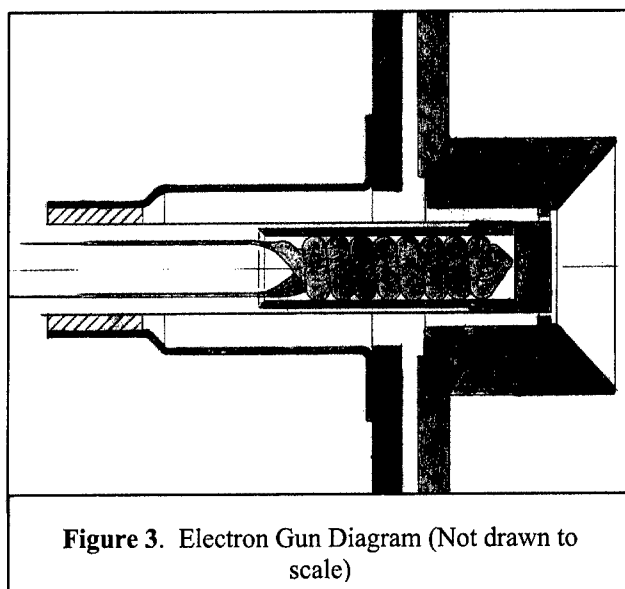
Table 1. Tube Data and Features

Number of beams: 7	Saturated power out: 500 watts with 3 beams Implies >2,000 watts for 7 beams
Number of cavities: 3	Beam transmittance DC: 99%
Average beam voltage: 5,000 volts	Beam transmittance at max. RF output: 65%
Cathode current per cathode: 114 ma	Saturated gain (3 beams): 25 dB
Cathode diameter: .080 inches	Frequency: 5.86 GHz
Basic efficiency: 50%	Lens voltage = 4,000 volts
Unloaded Cavity Q: 2,000	Beam tunnel diameter: .080 inches

To prevent RF leakage at the cavity split, an RF choke is employed by judicious dimensioning of the insulator and use of steps in the metal interfaces, as shown in Figure 4. This approach has been successful in preventing RF leakage at the cavity splits. Unloaded Q is routinely above 2,000.

Average beam potential at cavity gaps is 5,000 volts. However, for best focusing, the input side of the gap operates at 3,000 volts and the output at 7,000 volts. This was sufficient to produce DC beam transmittance of 99%. However, at saturated RF output, transmittance drops to 65%. The lost electrons are falling on the output wall of the output cavity. We will discuss this problem and measures we are taking to remedy it.

The first prototype produced 500 watts of output power with only 3 electron beams. The second prototype is nearly ready to test, and is expected to produce 2,000 watts with all 7 beams operating. The first prototype had saturated gain of 25 dB. The tube weighs under 3 pounds.



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